Topical Fluorides

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The American Association for Dental, Oral, and Craniofacial Research (AADOCR) supports the use of topical fluorides as a safe, effective, and evidence-based intervention for the prevention of dental caries (tooth decay). Dental caries is among the most prevalent human diseases globally, especially in children in low-socioeconomic groups and minorities.[1,2] The significant implications of good oral health on overall health are being increasingly appreciated.[3,4] The number of people with oral diseases was estimated at 3.5 billion worldwide, of which 2.3 billion (66%) appeared to have untreated disease.[5] The global prevalence of dental caries remained generally unchanged between 1990 and 2017.[5] Within the United States, the prevalence of caries experience in adults is estimated to be 90%, with 21.3% of adults having untreated decay,[6] while the prevalence of untreated or restored dental caries in one or more primary or permanent teeth in children ages 2-19 years is 46.0%.[7] The Centers for Disease Control and Prevention's (CDC) Division of Oral Health identifies oral health disparities among groups defined by race or ethnicity, socioeconomic status, gender, age, and geographic location. These disparities are due largely to the varied prevalence of water fluoridation, access to dental care, and social and commercial determinants of health. Suboptimal oral health has been shown to negatively impact learning, particularly in early life.[8]

The promotion of using various fluoride-containing agents is a major strategy for preventing dental caries.[9,10] The major mechanisms by which fluorides protect tooth surfaces are based on ultrastructural changes in (partly) fluoride-substituted tooth mineralized phases that resist decay-causing acids produced by cariogenic bacteria, and antimicrobial effects of high concentration topical fluorides.[11-15] The biochemical basis of partial fluoride substitution has been attributed to several key factors, including dose, phase of tooth eruption, and mode of delivery, either topical or systemic delivery, all of which have significant clinical and public health implications. Recent controlled clinical trials and systematic reviews with meta-analysis have found that topical fluoride preparations, such as sodium fluoride and silver diamine fluoride (SDF), are moderately effective at preventing early childhood caries.[16,17] The use of these formulations also for dental erosion, hypo-mineralization lesions, and post-restorations has been suggested.[18-21]

Fluoride can be delivered topically or systemically. Topical fluoride is a common and effective method for preventing dental caries, strengthening teeth already present in the mouth, and enhancing oral health.[22] It is typically administered via direct application of

fluoride to the surface of the teeth. There are several forms of topical fluoride including but not limited to:

(i) toothpaste that contains fluoride in concentrations typically ranging from 1,000 to 1,500 parts per million (ppm).[23] Prescription-strength fluoride toothpastes contain 5,000 ppm fluoride as sodium fluoride.[23] Fluoride toothpaste should be used at least twice per day and provides a low level of fluoride exposure that aids in the continuous protection of teeth.[23]

(ii). gels and foams are usually used for more concentrated treatments and are often recommended for individuals at higher risk for dental caries. Products available in the U.S. include gels and foams of acidulated phosphate fluoride (12,300 ppm fluoride) and 2% neutral sodium fluoride products (~9,000 ppm fluoride).[23]

(iii). varnishes are available as sodium fluoride (~22,600 ppm or 11,300 ppm fluoride) or difluorosilane (1,000 ppm fluoride) and provide a concentrated fluoride treatment that bonds to the enamel and slowly releases fluoride over time.[23,24] Although the fluoride concentration of most commonly used varnishes (5% NaF) is notably higher than the concentration in other topical fluoride products, the nature of varnish lends itself to controlled, precise application to specific tooth surfaces.[25] Varnishes are often used in dental offices or community-based settings for children and adults at a higher risk for dental caries and those who need additional protection.

(iv). mouth rinses provide a lower concentration of fluoride exposure compared with gels and varnishes. Over-the-counter solutions of 0.05% sodium fluoride (~230 ppm fluoride) and 0.02% sodium fluoride (~100 ppm fluoride) for daily rinsing are available for use by persons older than 6 years of age.[23, 26] Higher strength mouthrinses for those at high risk of tooth decay may be prescribed by a dentist or physician.[23] Solutions of 0.2% sodium fluoride (~920 ppm fluoride) are also used in supervised, school-based weekly rinsing programs.[23]

(v). silver diamine fluoride is commonly available as a 38% solution containing 44,800 ppm fluoride ions.[27] It is recommended that clinicians prioritize the use of 38% SDF solution (biannual application) over 5% NaF varnish (application once per week for 3 weeks) to arrest advanced cavitated caries lesions on any coronal surface of teeth.[28, 29]

Topical fluorides can be applied within professional settings (varnishes, solutions, gels, or foams) or individually applied (toothpastes and mouth rinses) as part of a regular oral hygiene routine.

Mechanisms of Action and Effectiveness

Topical fluoride benefits oral health through several primary mechanisms. The placement of fluoride directly on the enamel, such as with toothpastes, gels, varnishes, and foams, reduces demineralization and aids in the remineralization of enamel that has been demineralized by acidic attacks from bacteria.[23] It also promotes the deposition of calcium and phosphate back into the enamel, enhancing its resistance to future acid attacks.[23] Additionally, fluoride reduces the solubility of the enamel when under acidic conditions, thereby reducing the loss of minerals during acid attacks.[30] This protective effect helps maintain enamel structure during periods of low pH in the mouth. By integration into the enamel structure, fluoride increases its hardness and resistance to both mechanical and chemical stresses.[30] This fortification helps protect enamel from physical and chemical wear, further contributing to oral health. The application of fluoride through products such as SDF also has a significant antibacterial effect, impacting cariogenic bacteria such as *Streptococcus mutans*, responsible for tooth decay.[31,32]

Brushing with fluoride toothpaste increases the fluoride concentration in saliva by 100- to 1,000-fold. After one to two hours following using fluoride toothpaste, the saliva concentration returns to the baseline level.[33] Fluoride toothpaste containing over 1,000 ppm of fluoride prevents dental caries in the permanent and primary dentition.[34] The professional application of fluoride varnish or fluoride gels to children's teeth two or more times per year shows successful results in the prevention of caries in high-risk caries children of all ages, regardless of the fluoride levels in drinking water.[22] Fluoride varnishes have means of 37% effectiveness in preventing caries primary teeth and 47% on permanent teeth.[35]

Safety, Risks, and Toxicity

The use of topical fluoride in appropriate and recommended forms and with appropriate dosages is considered safe.[36,37] Self-care topical fluoride products are formulated with specific concentrations of fluoride that are deemed safe for daily use.[35] Higher fluoride concentrations in gels and varnishes, applied professionally, are also safe and beneficial when used appropriately.[37] Extensive research and many clinical studies have demonstrated the efficacy and assessed the risks and established the safety of topical fluoride.[14-22, 37-42] The Food and Nutrition Board (FNB) of the National Academies of Sciences, Engineering, and Medicine has established recommended upper limits (UL) for fluoride intake from all sources for healthy individuals based on levels associated with dental and skeletal fluorosis. These levels range from 0.7 mg in children ages birth to 6 months and 10 mg in those over 9 years of age.[43] These daily tolerable UL for fluoride exceed expected dosages from professional and individual uses of topical fluoride products. The U.S. Preventive Services Task Force recommends the

clinical application of fluoride varnish to the primary teeth of all infants and children starting at the age of primary tooth eruption.[44] The recommendation is given a “B” grade, indicating that there is high certainty that the net benefit of the intervention is moderate or there is moderate certainty that the net benefit is moderate to substantial.[44] Health organizations such as the American Dental Association (ADA) and the World Health Organization (WHO) endorse the use of fluoride for caries prevention.[36,45] The guidelines provided by these organizations are based on a robust body of evidence supporting fluoride's role in dental health.

The caries-preventive effects of fluoride have been noted to be additive when fluoridated toothpastes are used alongside fluoridated water. While topical fluoride is safe, excessive fluoride intake during the formative years of dental development can lead to dental fluorosis,[46] a condition characterized by changes in the appearance of tooth enamel. In the U.S., dental fluorosis is mostly mild and cosmetic, does not affect tooth function and is not painful.[47] Moderate and severe forms of dental fluorosis are rare.[48] To mitigate the risk of fluorosis, parents should supervise young children while brushing to ensure they use only a small amount of toothpaste (i.e., a grain of rice-sized and pea-sized, respectively, for children younger than 3 years old and aged 3 to 6 years and avoid swallowing it.[49-52] Varnishes and gels are designed for topical application and are not intended for ingestion.

Current AADOCR evidence-based position on topical fluorides

Based on current evidence-based science, the American Association for Dental, Oral, and Craniofacial Research (AADOCR) supports the following recommendations:

1. Fluoride-containing dentifrices (1,000-1,500 ppm) should be used routinely twice daily to effectively prevent caries. Brushing with fluoride toothpaste twice daily is a crucial part of a comprehensive oral health routine and incorporating this habit is key to maintaining long-term oral health.
2. Fluoride-containing dentifrices should be used in very small amounts in young preschool-aged children to reduce the risk of dental fluorosis through unintentional ingestion.
3. Daily or weekly fluoride mouth rinses should be used by adults and school aged children at elevated risk of dental caries. Because of their high fluoride concentration, mouth rinses are not recommended for preschool-aged children.
4. Fluoride gels and varnishes should be applied professionally at three- to six-monthly intervals as appropriate for patients at increased caries risk. Application frequency should be decreased or increased according to risk status and degree

of exposure to other sources of fluoride. Higher-risk patients should receive applications at three- to four-month intervals.

5. 38% SDF solution should be applied biannually applied on top of 5% NaF to arrest advanced cavitated carious lesions on any coronal surface of primary or permanent teeth, if access to care is limited, those with special health care needs, or for patients when general anesthetic is not considered safe.

Based on the current literature, AADOCR notes that additional investigation is warranted concerning chronic systemic toxicity of fluorides.

Author Contributions

P. Arany contributed to design, data acquisition, analysis, and interpretation, drafted and critically revised the manuscript, all members of the AADOCR Science Information Committee sub-committee, contributed to conception and design, critically revised the manuscript. M.K.S. Charles-Ayinde contributed to conception, design, and interpretation of the manuscript; C. Fox contributed to the conception and critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of the work.

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